Forest Research Report No. 127

Field Performance of Black Spruce Container Stock

Number 1. Comparison of two growing environments and four container types - Second-year field results from 1989 outplanting.

Ministry of Natural Resources
Ontario

Cover Photo:
Typical Northern Ontario Upland Black Spruce Cutover, prepared for establishment of Research Container Trial.

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Ministry of Natural Resources
Ministère des Richesses naturelles

Canadian Cataloguing in Publication Data

Paterson, John (John M.)
Field performance of black spruce container stock. Number 1. Comparison of two growing environments and four container types, second year field results from 1989 outplanting

(Forest research report, ISSN 0381-3924 ; 127)
ISBN 0-7729-9104-9

1. Black spruce - Seedlings, Container.
2. Black spruce - Seedlings - Evaluation.
I. Ontario Forest Research Institute.
II. Title.
III. Series.

SD404.3P37 1991 634.9'752 C92-092501-4

© 1991, Queen's Printer for Ontario
Printed in Ontario, Canada

Single copies of this publication are available at no charge from the address noted below. Bulk orders may involve charges.

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Cette publication scientifique n'est disponible qu'en anglais.

92-06037/

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Paterson, John M., 1991. Field Performance of Black Spruce Container Stock.

Number 1. Comparison of two growing environments and four container types - Second year field results from 1989 outplanting. Ontario Ministry of Natural Resources, Forest Research Report No. 127. 13 p.

ABSTRACT

Black spruce (*Picea mariana* [Mill.] B.S.P.) overwintered container crops produced in four container types (FH408 Paperpot, Multi-pot #1-67, Multi-pot #3-96, Multi-pot #6-45) and two growing environments (greenhouse and outdoors) were compared in outplanting trials during the spring of 1989.

At time of planting, the outdoor-grown crop was shorter in height, smaller in root collar diameter and had less oven-dry weight than the crop produced in the greenhouse, for any given container type. First-year annual increment for the outdoor-grown crops was almost double that of the greenhouse-grown crops. The greater growth rate of the outdoor-grown trees continued into the second field growing season, and initial differences in total heights between the two crops were negligible after only two field growing seasons. Second-year field results illustrate that growing environment and container type both influence plant size during the growing phase, but that field performance after outplanting may be more related to the initial growing environment conditions.

INTRODUCTION

Ontario nurseries produced over 163 million forest tree seedlings during 1988. Black Spruce (*Picea mariana* [Mill.] B.S.P.) made up 68 million or 42% of the total production (Ministry of Natural Resources (MNR)- Statistics 1988-1989). Roughly 44% of the total stock produced was grown in containers by private nurseries under contract to the Ministry of Natural Resources. The predominant container type used within the province is the FH408 Japanese Paperpot. Contracts to private container nurseries within Ontario's Northern Region presently require black spruce to meet the following morphological standards: minimum total height of 10 cm to a maximum of 25 cm, with target total oven-dry weights of 350 to 1,000 milligrams, shoot-to-root ratios of 3.5 to 1, and height-to-diameter ratios of < 120 to 1 (Gillham, pers. commun.)[2]. Crops traditionally grown in the FH408 paperpot would meet this criteria, but heavier stock reaching 1,500 mg and approaching 25 cm in total height were being requested by some forest management agreement holders (Stanclik 1986).

During 1988, Charles Warner of Aidie Creek Gardens Inc., Englehart, Ontario, under contract to the Northern Forest Development Group (NFDG) of the MNR, set out to investigate alternative container types and methods of production which would consistently produce stock greater than 800 mg in total dry weight and greater than 20 cm in total height with shoot-to-root ratios of less than four (Warner 1989). Scarratt (1982) suggested that black spruce container stock should have a height of 20 cm and a total dry weight of 1.0 grams as a minimum in order to match the height growth performance of bare root stock. Scarratt (1982) also suggested that although these sizes were attainable in the FH408 paperpot, alternate container types would be preferable, and that plug-type containers (e.g., Multi-pot) would be a viable alternative to the FH408 paperpot.

Container volume plus the density of plants per square meter (aerial growing space) have been shown to have a strong influence on the morphological quality of seedlings (Day and Sutherland 1986, Scarratt 1982). Warner, in an attempt to produce larger container stock, used six container types including plugs and paperpots, six seeding dates and three growing environments.

Field testing of a portion of the new stock types produced was done by the Ontario Forest Research Institute in cooperation with C. Warner to determine how the field performance of the new stock types compared to that of the traditional greenhouse-grown FH408 paperpots. The morphological characteristics of the seedlings being field-tested plus first- and second-year field results are reported in this paper.

MATERIALS AND METHODS

Although six container types, three growing environments and six seeding dates were tested in Warner's 1988 study (Appendix 1), only four container types (FH408 Paperpot, Multi-pot #1-67, Multi-pot #3-96, Multi-pot #6-45) and two growing environments (Greenhouse and Outdoors) for one seeding date (April 15) were used for

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[2] Gillham J., Operations Manager, Northern Forest Development Group, Ministry of Natural Resources, Northern Regional Office, Timmins, Ontario.

outplanting during the spring of 1989. The growing density and container volumes of these containers are shown in Table 1. The growing environments covered the extremes from a relatively controlled environment (greenhouse) to an uncontrolled environment (outdoors). The seeding date chosen was the one which was traditionally used operationally to produce an overwintered crop.

Table 1. Container type showing plant density and container soil cavity volume.

CONTAINER TYPE	DENSITY (plants per m^2)	SOIL CAVITY VOLUME (cm^3)
Multi-pot #6-45	581	105
Multi-pot #3-96	441	99
Multi-pot #1-67	850	57
Paperpot FH408	958	83

All the stock was germinated in the greenhouse (roughly two weeks) and then moved to its appropriate growing environment for an additional 14-16 weeks. The greenhouse stock was then moved to an outdoor holding area, in close proximity to the outdoor grown stock, for hardening and overwintering. Overwintering was carried out in traditional outdoor holding areas with containers placed on the ground, protected along the perimeter by wooden planks and from the top by snow fencing, and then left to be buried under natural snowfalls until spring.

The 1989 field planting site was located on a previously shear-bladed silt loam site in Gross Township, Kirkland Lake District, within the Ministry of Natural Resources' Northern Region. The planting was carried out on May 10, 1989, and all trees were planted using Potti Putkis in the FH408 size. Prior to planting, the total height from the root collar to the base of the terminal bud and root collar diameter of each tree were measured. Height/diameter ratios were then calculated on a per-tree basis. The planting was a randomized complete block consisting of four container types x two growing environments (eight treatments) with four replications of 35 trees each for a total of 1120 trees.

Separate random samples of 40 trees per treatment were collected for destructive sampling just prior to planting and the following morphological characteristics were assessed: total height, root collar diameter, top dry weight and root dry weight. Total dry weights, shoot/root ratios and height/diameter ratios were calculated. The number of needle primordia contained within the terminal buds was also assessed using techniques outlined by Templeton *et al.* (1991). An analysis of variance for a completely randomized sample was performed, and if treatments were found significant, a Student-Newman-Keuls (SNK) multiple range test was applied at the 95% confidence level.

During the fall of 1989 and 1990, each planted tree was assessed to determine survival, planted height (in 1989 only) from the top of the soil surface to the base of the new growth, and total height from the top of the soil surface to the base of the terminal bud. Annual increment for each year was determined by subtraction. Significance of

differences between treatment means for planting heights, first- and second-year total heights and annual increments, plus second-year percentage survivals, after arc sine data transformation, were analyzed using an analysis of variance for a randomized complete block design, and if found significant, a SNK multiple range test (p = 95%) was applied.

RESULTS AND DISCUSSION

Morphological Characteristics

Table 2 summarizes the morphological characteristics of the stock used in the 1989 planting. Growing environment and container type both influenced tree size at the end of the nursery rearing period. Greenhouse-grown stock was taller than outdoor-grown stock. Seedlings grown in the Multi-pot #3-96 (greenhouse environment) had significantly greater total heights than seedlings grown in all container types in the outdoor environment, and were significantly taller than all container types within the greenhouse environment with the exception of the Multi-pot #1-67.

Root collar diameter, although influenced by growing environment, appeared to be more affected by container type. The influence of container type may be a function of plant density and container volume since the Multi-pot #3-96 and #6-45, which were the two larger containers, allowing for more aerial growing space (Day and Sutherland 1986), were not significantly different from each other within each growing environment, but were both significantly larger in diameter when compared to the Multi-pot #1-67 and FH408 Paperpot.

The FH408 Paperpot had the highest height/diameter and shoot/root ratios within the outdoor environment, whereas the FH408 Paperpot and Multi-pot #1-67 had significantly higher ratios in the greenhouse environment. No other container types were significantly different within and between growing environments.

The Multi-pot #3-96 stock grown in the greenhouse environment had significantly greater numbers of needle primordia than the Multi-pot #1-67 and FH408 Paperpot grown in the greenhouse environment, and also significantly more than the Multi-pot #6-45 grown outdoors. No significant differences in numbers of needle primordia were observed among container types within the outdoor environment.

Seedlings grown in the Multi-pot #3-96, greenhouse environment, had significantly greater total oven-dry weight than all other container types from either growing environment. Johnson (1974) showed for Paperpots that seedling size was a function of container diameter and volume, and Day and Sutherland (1986) showed that container volume exclusively influenced seedling growth. The Multi-pot #3-96 which has the least density of plants per square meter with the second largest soil cavity volume has produced the largest seedlings. Seedlings grown in the Multi-pot #1-67 and FH408 Paperpot in the outdoor environment plus the FH408 Paperpot stock grown in the greenhouse environment had significantly less oven-dry weight than all other container types within the two growing environments.

Table 2. Morphological characteristics at time of planting of stock grown in two environments and four container types.[3]

Container Type by Environment	Total Height (mm)	Root Collar Diameter (mm)	Height/ Diameter Ratio	Number of Needle Primordia	Total Oven Dry Weight (mg)	Shoot/Root Ratio
GREENHOUSE ENVIRONMENT						
Multi-pot #6-45	247 bc	2.89 a	87 b	197 ab	1982 b	5.7 b
Multi-pot #3-96	270 a	3.01 a	90 b	247 a	2259 a	5.0 b
Multi-pot #1-67	260 ab	2.48 b	106 a	143 b	1591 c	7.7 a
FH408 Paperpot	239 c	2.21 c	110 a	141 b	1288 d	8.0 a
OUTDOOR ENVIRONMENT						
Multi-pot #6-45	186 d	2.23 c	84 b	155 b	1578 c	4.8 b
Multi-pot #3-96	193 d	2.36 bc	83 b	221 ab	1984 b	5.7 b
Multi-pot #1-67	162 e	1.83 d	89 b	196 ab	1164 de	5.3 b
FH408 Paperpot	178 d	1.75 d	103 a	169 ab	1053 e	8.8 a

All of the container types from both growing environments produced trees which, with the exception of the shoot/root ratios, met the current Northern Region's contracted morphological standards for black spruce container stock. In fact, Warner's original study to look at alternative methods to produce larger container stock has shown that the Multi-pot #3-96 and #6-45 container types, without altering normal seeding dates (April 15 for overwintered stock), can produce seedlings that exceed the current Northern Region's specifications. However, the field performance of these trees varied considerably between container types and between growing environments during the first two years after outplanting.

Survival and Growth

Container type and growing environment did not appear to have any influence on the ability of the stock to survive after outplanting. Survival for all treatments was at least 94% (Table 3) by the end of the second year, and no significant differences in survival among treatments were observed.

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[3] Based on laboratory measurement of random sample taken at time of planting. Numbers followed by the same letter within a column, are not significantly different at the 95% confidence level.

Table 3. First- and second-year field performance comparing stock grown in two environments and four container types.[4]

Container Type by Environment	Percent Survival	Planting Height	1989 Total Height	1990 Total Height	1989 Increment	1990 Increment
GREENHOUSE ENVIRONMENT						
Multi-pot #6-45	95 a	301 a	359 a	408 ab	58 c	62 d
Multi-pot #3-96	99 a	257 b	339 a	422 a	82 b	91 abc
Multi-pot #1-67	95 a	249 b	300 b	371 bc	51 c	83 c
FH408 Paperpot	98 a	241 b	299 b	376 bc	58 c	88 bc
OUTDOOR ENVIRONMENT						
Multi-pot #6-45	96 a	162 c	270 bc	360 c	109 a	113 a
Multi-pot #3-96	96 a	168 c	280 bc	372 bc	112 a	109 ab
Multi-pot #1-67	99 a	159 c	270 bc	346 c	111 a	97 abc
FH408 Paperpot	94 a	147 c	237 c	298 d	90 b	92 abc

After planting, the seedling planting height for all container types grown in the outdoor environment was significantly shorter than seedlings grown in all four container types in the greenhouse environment (Table 3), and no significant differences existed among seedlings grown in the four container types in the outdoor environment. Although the Multi-pot #3-96 crop grown in the greenhouse environment was the tallest in the sample taken for the morphological data (Table 2), the Multi-pot #6-45 crop is now significantly taller after planting. This was likely due to sample variation within the container trays and differences in planting depths that occurred during the planting operation. Growing environment had a significant influence on tree height at time of planting, with the greenhouse-grown trees being taller than those produced in the outdoor environment. Container type had no significant effect on the planting heights of outdoor-grown trees, and only trees grown in the Multi-pot #6-45 differed significantly in height from the trees grown in the three other container types in the greenhouse environment.

There is currently great interest in the use of height/diameter ratios as a stock grading guideline in Ontario. However, there is little data to support its operational use. In this trial, the pre-plant height and diameter measurements taken on each tree and the

[4] Results based on trees surviving after two field seasons. Numbers followed by the same letter within a column, are not significantly different at the 95% confidence level.

resulting height/diameter ratios are being used to monitor field performance related to initial stock size at time of planting. Further analysis of this data and additional data from a duplicate study established in 1990 will be reported at a later date (Paterson, in preparation).

After the first growing season, the 1989 total heights of the Multi-pot #6-45 and #3-96 and #1-67 crops from the outdoor environment were no longer significantly different from those from the Multi-pot #1-67 or the Paperpot FH408 from the greenhouse environment (Table 3). Both the Multi-pot #6-45 and #3-96 stock from the greenhouse environment were significantly taller than all other stock types. Immediately after planting, the crops from the greenhouse environment were 39% taller than crops from the outdoor environment, and still remained taller after one field season; however, this difference decreased to only 19%.

After the second season (1990 total height), the Multi-pot #3-96 stock from the greenhouse environment was still significantly taller than all other stock types except for the greenhouse environment Multi-pot #6-45 stock (Table 3). The Paperpot FH408 stock from the outdoor environment was significantly shorter than all other stocks from both environments. Growing environment and container type effects were still evident after two growing seasons, but due to the increased second-year increment on the outdoor-grown crops, the difference in total height between outdoor-grown and greenhouse-grown crops was further reduced to only 13%.

The differences in initial total height between the greenhouse-grown crops and the outdoor-grown crops were reduced in 1989 and again in 1990 (Table 3), due to an increase in annual increment on the outdoor-grown crops. All outdoor-grown crops in Multi-pots had significantly greater first-year annual increments (1989 increment) than all crops produced in the greenhouse environment. Therefore, while the growing environment contributed greatly to initial crop size, with the greenhouse environment producing the tallest trees, first-year field performance indicated that the trees grown in the outdoor environment achieved greater increments.

Increments in the second season (1990 increment) remained significantly greater for the crops produced in the outdoor environment (Table 3). The Multi-pot #6-45 greenhouse-grown crop, which was the tallest at planting, produced the least amount of second-year annual increment. The increment was significantly shorter than all other stock types from either environment. The crops produced in the outdoor environment achieved 21% more annual increment in the second year than those produced in the greenhouse environment. Although the outdoor-grown Paperpot FH408 was the shortest at planting (planting height) and after the first field season (1989 total height), it grew significantly more annual increment in the first and second growing season than the greenhouse-grown Multi-pot #3-96 stock. It would appear, therefore, based on the first two years of increment, that the greenhouse crops took longer to adjust to the conditions encountered in the field environment. If this trend in reduced increment on the greenhouse-grown crops continues into the third growing season, the initial height advantages of greenhouse-grown crops will be negligible.

In summary: the greenhouse-grown crops, although larger at time of planting, have not been adequately pre-conditioned to endure the conditions faced at planting. The result has been reduced increment during the first two years after planting when compared to the outdoor-grown crops (Figure 1.).

This data has indicated that the stock's morphological characteristics do not

always reflect field growth potential. This was well stated by Day (1985) when he said that "the ability of nursery stock to function is probably more important than its appearance or size, and that it is probable that 'physiological quality' is more important than 'morphological quality' in determining the ability of stock to establish and grow after outplanting." Although we did not assess the physiological condition of the trees from the two environments, it is probable that the seedlings grown outdoors were subjected to drought stress, nutrient stress, heat and cold stress and variations in light intensities which closely simulated the conditions they would face after planting. McClain (1986) referred to this form of conditioning as "active: the application of cultural or handling procedure directed toward a seedling lot for purposes of improving its field performance potential." Crops grown in the greenhouse environment were probably not subjected to stresses that were as severe during their growing phase, and so did not receive similar active conditioning. This stress-related pre-conditioning experienced by the outdoor-grown crop coupled with its smaller size probably allowed it to be less affected by what may have been harsh handling and planting and site and environmental conditions encountered during and after planting.

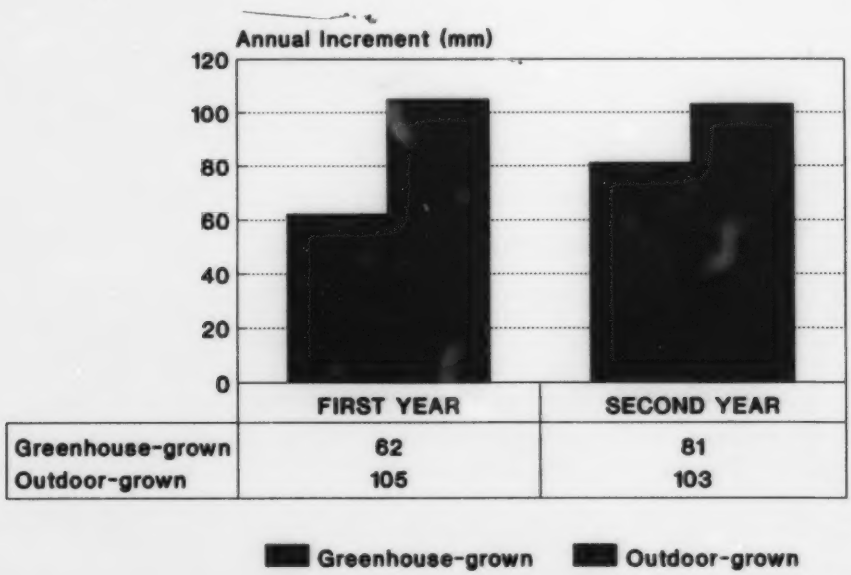

Figure 1. First- and second-year annual increment by method of production (greenhouse-grown, outdoor-grown), all container types combined.

Monitoring of this study will continue at least until the fifth year to see if the initial height advantages of the greenhouse-grown crops will prevail over their smaller counterparts produced in the outdoor environment.

CONCLUSIONS

Some Forest Management Agreement Holders have been requesting larger container stock, as a possible replacement to medium-sized bare-root trees, for planting on sites prone to heavy competition. However, this study has shown that although trees of various sizes can be grown by altering the container type or the growing environment or a combination of both, the larger trees have not performed as well in first- and second-year increment. The additional costs to produce the larger trees (greenhouse crops) have not been realized in improved plantation performance.

The crops produced in the greenhouse started out with an initial height advantage of 39% over those produced in the outdoor environment. This initial height advantage was reduced to only 19% by the end of the first field season and to only 13% by the end of the second season. Crops produced in the greenhouse had greater difficulty producing growth equal to that attained by the outdoor-grown crops.

The challenge facing nursery managers is to produce container crops which will survive and grow rapidly following planting. This study has demonstrated the effects of growing environment and container type on field performance in the first two years after planting.

As demonstrated by the results of this study, greenhouse-grown and outdoor-grown crops differed in field performance. These differences may be due in part to differences in seedling physiology. These apparent physiological changes need to be determined, and nursery cultural practices modified, to allow nursery managers to reliably and repeatedly produce stock possessing desirable field establishment characteristics.

ACKNOWLEDGEMENTS

I wish to thank Charles Warner, who supplied the stock used in this experiment; Randy Morrison and Ray Hong of the Kirkland Lake District, who supplied assistance and support in establishing the trial; the Northern Forest Development Group, who had the foresight to initiate a study to investigate alternative methods of producing larger container stock; and the staff within the Forest Renewal Group at the Ontario Forest Research Institute, for their ongoing support.

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APPENDIX

Appendix 1. Experimental treatments applied to develop alternative methods of production for growing larger container stock. (from Warner, 1989)

GROWING ENVIRONMENTS

Greenhouse	-	with heat and ventilation
Cold Frame	-	no heat but with exhaust fan ventilation
Outdoors	-	shade cloth for frost protection, otherwise no protection.

SEEDING DATES

March 15	-	grow for 1 season, overwinter then plant
April 1	-	grow for 1 season, overwinter then plant
April 15	-	grow for 1 season, overwinter then plant
May 15	-	grow for 2 seasons, overwinter twice then plant
June 15	-	grow for 2 seasons, overwinter twice then plant
July 15	-	grow for 2 seasons, overwinter twice then plant

CONTAINER TYPES

Japanese FH408 Paperpot	89 cavities per square foot
ROPAK Multi-pot #1-67	79 cavities per square foot
ROPAK Multi-pot #3-96	41 cavities per square foot
ROPAK Multi-pot #4-96	41 cavities per square foot
ROPAK Multi-pot #6-45	54 cavities per square foot
ROPAK Multi-pot PG45125	53 cavities per square foot